TARDEC

---TECHNICAL REPORT---

THE NATION'S LABORATORY FOR ADVANCED AUTOMOTIVE TECHNOLOGY

No. 13802

LAB TEST OF PROTOTYPE
HMMWV FILTER ELEMENTS
CONSTRUCTED WITH SPUNBOND
POLYESTER MEDIA

JULY 2001

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13. ABSTRACT ***(Maximum 200 Words)***

Lab test results showed the spunbond polyester media met efficiency requirements but failed the dust capacity/service life requirement. The spunbond polyester media achieved an efficiency of 99.88 % which exceeds the required 99.5 %. The spunbond polyester media achieved a service life of 3.4 hours during dust capacity tests. This falls way short of meeting the present specified service life requirement of 20 hours (recently waived to 16 hours in a recent contract). Initial restriction of spunbond polyester media was considered acceptable and only slightly higher in one HMMWV prototype than the two comparison HMMWV production filter elements lab tested.

Dust capacity lab test results based on the Army's current test methods and procedures showed the spunbond polyester media would not be considered acceptable for use on military vehicle based on HMMWV air filter test results. Lab test results do not consider vibration effects as would be seen by a filter element installed on a military vehicle. It is not known if spunbond polyester media performance would increase significantly if vibration effects were incorporated during dust capacity tests as measured on vehicle during running.

14. SUBJECT TERMS
spunbond media, restriction, polyester media, air intake,pressure drop, dust capacity, airflow, initial efficiency, service life

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FOREWARD:

The spunbond polyester media lab test investigation was performed for the Propulsion Product Support Team. A cost estimate was provided by the Mobility Test Operations Team. A cost of 10K was provided to conduct lab tests. The prototype HMMWV filter elements constructed with spunbond polyester media were provided by Mr. Dave Hubbard from SKIP's NW Filter Service.

Key personnel contributing to this project effort included the following:

- Mr. Michael J. Richards, Mobility Test Operations, responsible for air cleaner test set-up, instrumentation, conducting test, test data gathering and presenting test data in graphical and tabular form.

- Mr. Lawrence Sierpien, Mobility Test Operations, responsible for air cleaner test set-up, conducting test and gathering test data.

- Mr. Dave Hubbard, SKIP's NW Filter Service, responsible for providing two (2) prototype HMMWV filter elements constructed with spunbound filter media.

- Mr. Jamie Quaderer, Propulsion Product Support, Test Engineer involved in conducting air filter test and preparing final report.

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ABBREVIATIONS/ACRONYMS

ABBREV/ACRONYM	DEFINITION
P	Pressure
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
SAE J726	Society of Automotive Engineer Air Cleaner Test Code
PTI	Powered Technology Incorporated
SCFM	Standard Cubic Feet Per Minute
MM/CM	Millimeters/centimeters
CFM	Cubic Feet Per Minute
$^{O}F/^{0}C$	Degrees Fahrenheit/Degrees Centigrade
%	Percent
ft^3	Cubic Feet
IN^2	Square Inches
ft/min	Feet Per Minute
LBS/ft^3	Pounds Per Cubic Feet
H_20	Inches of Water
in	Inches
WB	Wet Bulb
DB	Dry Bulb
RH	Relative Humidity
Wt.	Weight
Eff	Efficiency
HG	Mercury
GFE	Government Furnished Equipment

1.0 BACKGROUND

A Trip was made to Ft. Lewis, Washington, on 8 December 1998 to review their air filter cleaning and recycling programs presently in place. At that meeting contact was made with Mr. Dave Hubbard from North West Filter Company, Inc. and Mr. Jesse Holt from Holt Distribution Company. These gentlemen showed Mr. Frank Margrif from TACOM two prototype HMMWV filter elements made with a material called spunbond polyester media. They claimed that the spunbond filter could be cleaned repeatedly without damage. At Appendix A is a description of the material and property specifications of spunbond polyester media and supplier comments. In comparison, the present HMMWV air filter is made from a paper base material (see Appendix B for laboratory analysis of paper media properties) and is more subject to damage during cleaning. The current TM maintenance procedures specify that after three cleanings the present HMMWV air filter is to be thrown away and replaced with new.

It was determined that to prove acceptance of a new air filter for the HMMWV a laboratory test evaluation should be conducted. Thus, TACOM agreed to seek funds to conduct a comparison laboratory test between: (1) prototype HMMWV air filter made with spunbond media and (2) standard HMMWV paper base air filter.

In the meantime Mr. Dave Hubbard obtained permission to put a prototype HMMWV air filter made with spunbond polyester media on a HMMWV during field exercises at Yakima Training Center in the summer of 2000. He requested that Frank Margrif obtain current and past oil analysis information on the HMMWV that would be tested at Yakima Training Center (See Appendix C). It was hoped that previous oil analysis data would show the silicon content (dust/dirt) with standard air filter in place. Then upon installing the prototype HMMWV air filter made with spunbond polyester media, engine oil samples would show a reduced silicon level.

The previous oil sample records for the HMMWV undergoing field testing at Yakima Training Center is shown at Appendix D. The oil sample records which were obtained at Yakima Training Center with the HMMWV prototype air filter made with spunbond polyester media were invalid since the air filter housing containing a center support structure broke causing increased dust levels into engine which jeopardized the accuracy of oil samples.

Since engine oil analysis recordings during field testing of spunbond polyester media was unsuccessful, it became more important to conduct lab tests. Mr. Dave Hubbard provided two (2) HMMWV prototype air filters made with spunbond polyester in later part of year 2000.

2.0 SUMMARY

Two HMMWV prototype air filters made with spunbond polyester media were lab tested. One was tested for efficiency and the other for dust capacity. The test results were compared to efficiency and dust capacity conducted on two (2) standard production HMMWV air filters.

Efficiency test results showed that spunbond polyester media achieved an efficiency of 99.88% when tested for one (1) hour. In comparison the production HMMWV air filter (made by Donaldson Company, Inc.) achieved an efficiency of 99.80%.

Dust capacity test results showed the spunbond polyester media achieved a dust capacity in terms of service life of nearly 3.4 hours. This falls way short of the production air filter which achieved 14.5 hours of service life. The spunbond media achieved an accumulative efficiency of 99.94% during dust capacity test which meet minimum requirement of 99.9%.

3.0 OBJECTIVE

The objective of the air filter tests was to conduct a minimum comparison between the Donaldson production filter elements and spunbond filter elements. The first comparison lab test was an efficiency test. One of the production filter elements was subjected to an efficiency test and one of the spunbond filter elements was subjected to an identical efficiency test. The second comparison lab test was a dust capacity test. One of the production filter elements was subjected to a dust capacity test and one of the spunbond filter elements was subjected to an identical dust capacity test.

4.0 TEST MATERIAL/TEST METHOD/TEST EQUIPMENT

4.1 TEST MATERIAL

Two (2) spunbond prototype HMMWV filter elements were provided for test. One (1) filter element had a screen covering on dirty or intake side. The other filter element had no screen covering on dirty or intake side (see Figure 1). Two (2) Donaldson production filter elements for the HMMWV were obtained from Air Flow Lab in Bldg 7. These two (2) filter elements were new but had been purchased several years ago for a previous test (see Figure 2). The prototype spunbond HMMWV filter element with no screen covering on intake had a measured square feet of media equal to 39.84 ft^2 and a corresponding face velocity of 10.5 ft/min. The other prototype spunbond HMMWV filter element with screen covering on intake side had a measured square feet of media area equal to 44.18 ft^2 and a corresponding face velocity of 9.5 ft/min. In comparison, the Donaldson production filter elements (only one was measured) had a media area measured at 53.72 ft^2 and a corresponding face velocity of 7.8 ft/min.

4.2 TEST METHOD

The HMMWV production and prototype filter elements were mounted in a HMMWV air filter housing. The spunbond filter element with no screen covering the dirty or intake side was used for efficiency test. The spunbond filter elements with screen covering the dirty or intake side was used for dust capacity test. The rationale for this selection was that the screen covering on dirty or intake side provided a lower initial restriction or pressure drop. A lower pressure drop with screen covering on intake of spunbond filter element would provide the longest dust capacity or service life.

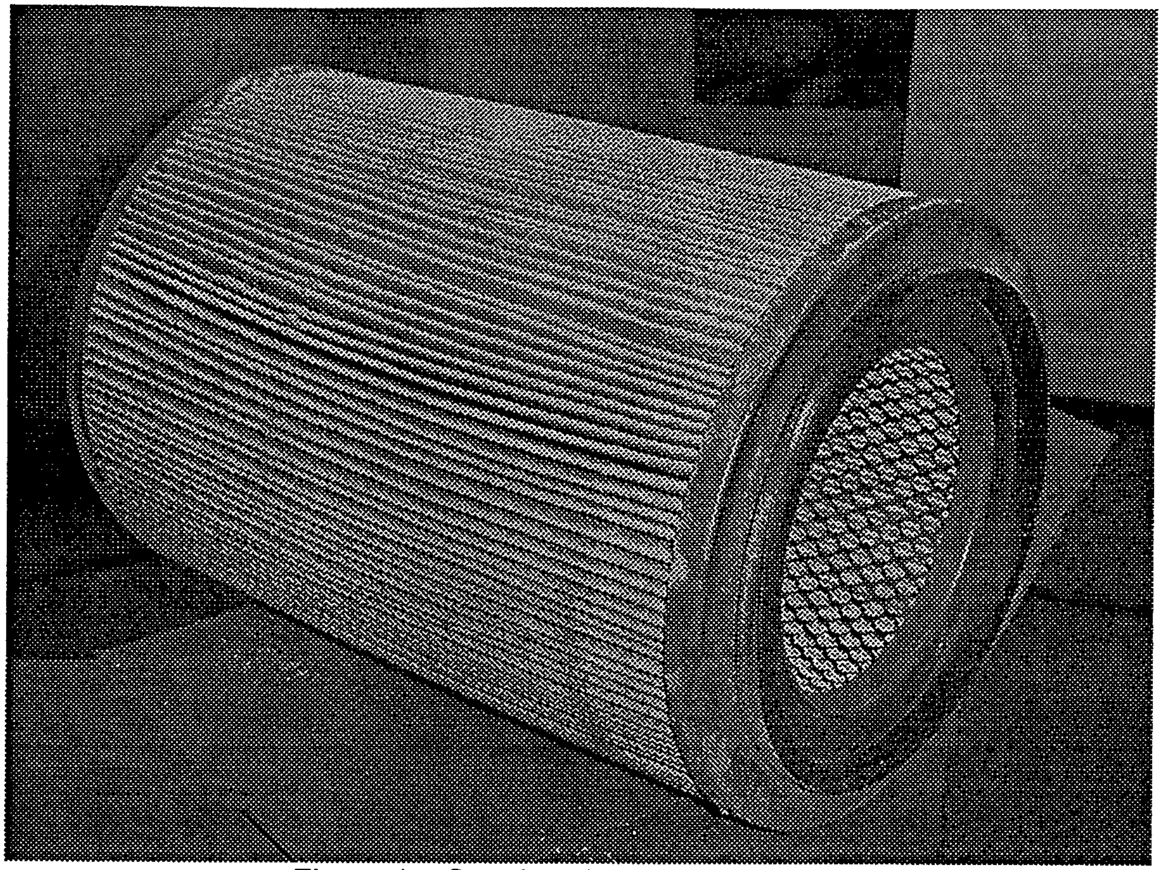


Figure 1 – Spunbond Prototype Air Filter

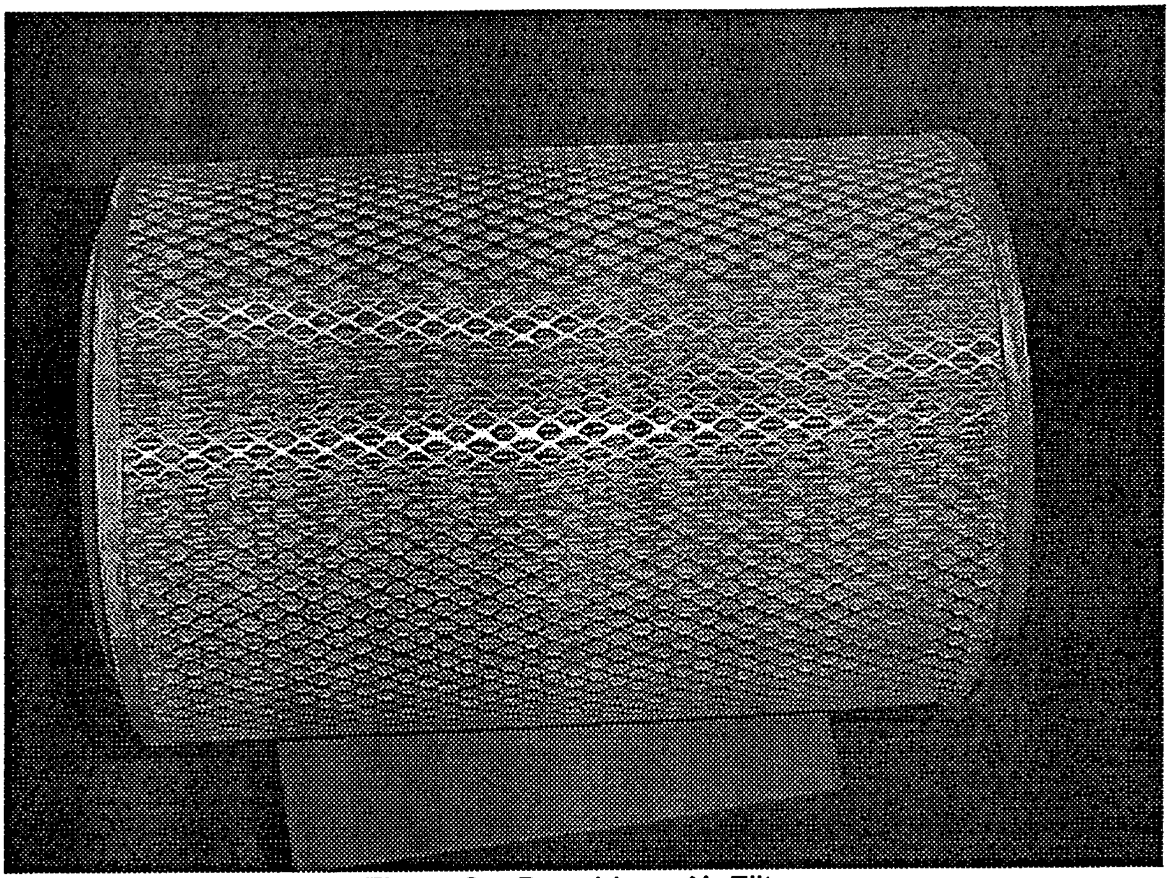


Figure 2 – Donaldson Air Filter

The efficiency and dust capacity tests were conducted according to MIL-F-46736E. The following exceptions to MIL-F-46736E were as follows. The efficiency tests for both the spunbond polyester filter element and Donaldson production filter element were ran for a period of 60 minutes. The normal period of running time is 30 minutes where the face velocity is 6 ft/min (183 cm/min) or more. For example, if the square feet of media area is 70 feet square and the rated air flow is 420 cubic feet per minutes, the face velocity is 6 feet per minute. Both the spunbond filter elements and Donaldson production filter elements had square feet of media area which produced face velocities of more than 6 ft/min and should have been tested for only 30 minutes. However, testing both filter elements to the same period of time is still considered a valid test.

It must also be noted that all testing was done without SAE J726 required use of a dust injection nozzle in the dust feeding system per MIL-PRF-46736E. The use of a dust injector nozzle is required per SAE J726 but not required per MIL-PRF-46736E. Donaldson Company, Inc. reported that there may as much as 3 hours service life reduction when dust capacity test is done with dust injector nozzle versus without dust injector nozzle. They reported a service life of 19.5 hours on a HMMWV filter element dust capacity test without dust injector nozzle installed. In comparison the service life dropped to 16.5 hours when dust capacity test was conducted with dust injector nozzle installed.

4.3 TEST EQUIPMENT

The test equipment and test facility is located at TACOM's Air Flow Lab (Bldg 7). Pertinent equipment used for these tests included: (1) accurate dust feeder; (2) test bench no. 2 600 CFM; (3) piezometer tube 4 in diameter and (4) nozzle size, 3 1/8 inch, 500 CFM.

5.0 RESULTS AND DISCUSSIONS

5.1 EFFICIENCY TESTING

5.1.1 DONALDSON PRODUCTION FILTER ELEMENT

The Donaldson Production filter element with a measured 53.72 square feet of media area was efficiency tested at 420 cubic feet per minute air flow. The test was ran for 60 minutes and SAE J726 fine test dust was used. After testing, the efficiency was measured at 99.8%. The efficiency test data is shown in Table 1. The filter element performance specification requires a minimum efficiency of 99.5% and thus test results showed the requirement was exceeded. Even though, the efficiency test was suppose to have been ran for only 30 minutes, based on a face velocity of 7.8 feet per minute (exceeding the 6 feet per minute threshold) the test is considered valid.

Title: Eff Test #1
Comment: Donaldson Element
Date and Time: 02/08/2001 1:51:46 PM

Orifice Areas= 0.055905 C Constant= 0.99

Efficiency= 99.8 %

Time	Airflow SCFM	Aircleaner Delta	Master Filter Delta
0	417.5	5.86	12.76
10	412.9	7.14	12.25
20	419.2	7.97	13.09
30	421.2	8.35	13.55
40	417.7	8.83	13.35
50	418.8	9.15	12.78
60	419.7	9.93	12.66

WB	DB	RH
63	80.0	38%
63	80.5	37%
61	78.0	37%

Weightings and Calculations

Wt. Dust Feeder and Inlet Conductors Dust feeder, Dust, Dust Tray, Dust delivery hose, Inlet piezzometer tube, Smooth aproach nozzel, hose and hose clamp.	Before= After= Dust fed=	37697.7 37068.0 629.7
Wt. Air Cleaner Air cleaner housing, spacer hose, element and large clamp	After= Before=	6109.9 5757.8 352.1
Weight Scavage Scavage dust collector jar with two hoses and one clamp	After= Before=	1232.7 952.8 279.9
Weight Element	After= Before=	2401.3 952.8 1448.5
Outlet Conducters Outlet piezzometer tube, 12 clamps and master filter cover.	After= Before=	18455.7 18455.7 0
Master filter element	After= Before=	111.00 109.99 1.01

Missing Dust -3.25 grams

Table 1 – Donaldson Air Filter Efficiency Test

5.1.2 SPUNBOND POLYESTER FILTER ELEMENT

The prototype HMMWV spunbond polyester filter element with a measured 39.84 square feet of media area was efficiency tested at 420 cubic feet per minute airflow. The filter and SAE J726 fine test dust was used. After testing the efficiency was measured at 99.88%. The efficiency test data is shown in Table 2.

The filter element performance specification requires a minimum efficiency of 99.5% and thus test results showed the requirement was exceeded. Even though, the efficiency test was suppose to have been ran for only 30 minutes, based on a face velocity of 10.54 feet per minute (exceeding the 6 feet per minute threshold) the test is considered valid.

5.2 DUST CAPACITY AND/OR SERVICE LIFE TESTING

5.2.1 DONALDSON PRODUCTION FILTER ELEMENT

The Donaldson Production filter element (difference one from efficiency test) with a measured 53.72 square feet of media area was dust capacity tested at a variable airflow rate. Airflow was varied in 10 minute steps from 20% to 100% of rated airflow (420 cubic feet per minute). The step cycle is shown in performance specification MIL-PRF-46736E, page 7.

The test was ran with SAE J726 coarse test dust and testing was considered complete when the filter element pressure drop or air cleaner delta exceeded 20 inches of water restriction at 420 cubic feet per minute rated airflow. Test results are shown in Table 3, (sheets 1, 2 and 3) and Table 4. A graphical presentation of test results is shown in Figure 3.

Test results showed the Donaldson filter element achieved a maximum service life of 14.5 hours before reaching the 20 inches of water pressure drop across air cleaner.

The HMMWV's air cleaner service life was originally 20 hours, however, several years ago the HMMWV engine airflow increased from 380 to 420 cubic feet per minute. The increased airflow resulted from the engine being upsized from a 6.2 to 6.5 liter.

At the higher airflow, air cleaner manufacturers could not meet the 20 hours service life requirement. One HMMWV filter element manufacturer who had a contract to provide spare part filter elements paid for independent lab tests. These lab tests were conducted in October 1996 by Southwest Research Institute (SwRI). The lab tests confirmed that a 16 hour service life to 20 inches of water pressure drop across air cleaner was more appropriate and a waiver/deviation was granted for a 16 hour service life so that HMMWV filter elements could be procured. The original equipment manufacturer of the HMMWV air cleaner assembly still maintains they can achieve the 20 hour service life at the increased airflow of 420 cubic feet per minute. This was not confirmed when tested by SwRI where test data showed that only a 18.4 hour service life was achievable. Findings are detailed in Appendix E.

Title: Eff Test #2
Comment: Spunbond Element
Date and Time: 02/13/2001 1:17:11 PM
Orifice Areas= 0.055905 C Constant= 0.99

Time	Airflow SCFM	Aircleaner Delta	Master Filter Delta	WB	DB	RH
0	416.7	7.68	11.97	63.5	79.5	41%
10	415.9	11.85	11.95	60.5	74.0	46%
20	415.4	14.65	11.88	61.5	77.0	42%
30	414.1	16.93	12.16			
40	416.0	18.30	12.32			
50	413.8	19.64	12.68			
60	415.0	20.91	12.65			

Efficiency= 99.88 %

Weightings and Calculations

Wt. Dust Feeder and Inlet Conductors Dust feeder, Dust, Dust Tray, Dust delivery hose, Inlet piezometer tube, smooth approach nozzle, hose and hose clamp.	Before= After= Dust fed=	37062.4 36434.4 628.0
Wt. Air Cleaner Air cleaner housing, spacer hose, element, large clamp and scavage dust collector jar with two hoses and two hose clamps.	After= Before=	7690.0 7063.4 626.6
Wt. Scavage Scavage dust collector jar with two hoses and one clamp	After= Before=	1206.4 952.8 253.6
Wt. Element	After= Before=	2724.0 2380.2 343.8
Outlet Conducters Outlet piezzometer tube, 13 clamps and master filter cover.	After= Before=	18503.9 18503.9 0
Master filter element	After= Before=	108.64 107.90 0.74

Unaccounted Dust= 0.66

Table 2 – Spunbond Prototype Air Filter Efficiency Test

Title: Capacity Test #1
Comment: Donaldson Element
Date and Time: 02/13/2001 1:17:11 PM
Orifice Areas= 0.055905 C Constant= 0.99

Time	Airflow SCFM	Aircleaner Delta	Master Filter Delta				
0	417.5	6.20	12.90				
10	253.5	2.49	6.68		WB	DB	RH
20	77.3	0.35	1.77		63.5	79.5	41%
30	350.0	5.32	10.44		60.5	74	64%
40	260.4	2.86	7.15		61.5	77	42%
50	164.7	1.41	4.11				
1 HR	412.9	7.39	13.66				
10	284.0	2.33	7.29				
20	96.2	0.69	2.09				
30	344.3	5.26	9.97				
40	251.3	3.30	7.03				
50	253.1	3.28	7.05				
2 HRS	418.2	7.92	13.42				
2 HRS	415.5	7.83	13.46	Date and Time: 02/16/2001 09:46:14 AM			
10	247.8	3.48	6.68				
20	83.4	0.74	1.92		WB	DB	RH
30	335.9	5.43	10.17		61	76.0	0.4
40	246.8	3.70	6.52				
50	164.3	1.97	3.95				
3 HRS	415.9	8.40	13.18				
3 HRS	419.3	8.82	13.35	Date and Time: 02/16/2001 12:04:38 PM			
10	251.5	3.74	6.79				
20	84.3	0.81	1.86				
30	331.5	6.10	9.16				
40	249.7	4.01	6.79				
50	169.2	2.23	3.95		WB	DB	RH
4 HR	417.7	9.10	13.43		60.5	79.5	32%
10	249.6	4.20	6.80				
20	81.7	0.88	1.79				
30	336.9	6.84	10.20				
40	171.9	2.53	4.23				
50	412.4	9.17	13.16				
5 HR	415.8	9.59	13.95				
10	250.4	4.66	7.11				
20	86.5	1.13	1.99				
30	333.8	6.95	9.80				
40	251.5	4.77	6.65				
50	172.2	2.81	4.08				
6 HR	414.8	10.45	14.02				
10	252.6	5.02	6.66				
20	337.7	7.99	10.07				
30	313.9	7.16	8.77				
40	251.8	5.15	6.66				
50	168.9	3.05	4.17				

TABLE 3: DONALDSON HMMWV PRODUCTION FILTER TABULAR DUST CAPACITY TEST RESULTS

SHEET 1 OF 3

7 HRS	414.0	11.00	13.08
7 HRS	417.7	10.74	11.53
10	254.4	5.46	6.51
20	86.7	1.35	1.84
30	340.2	8.21	9.24
40	248.3	5.41	6.36
50	170.1	3.39	3.97
8 HRS	388.0	10.39	11.41
10	251.0	5.97	6.53
20	86.9	1.45	1.74
30	324.8	8.53	9.23
40	250.3	6.10	6.45
50	170.5	3.61	3.86
9 HRS	417.9	12.32	12.10
9 HRS	418.6	12.61	12.54
10	253.8	6.58	6.31
20	88.4	1.60	1.72
30	340.7	9.54	8.88
40	249.9	6.54	6.09
50	171.7	4.00	3.84
10 HRS	421.3	13.17	12.39
10 HRS	423.2	13.43	12.86
10	251.8	6.79	6.40
20	90.6	1.82	1.75
30	336.9	10.22	9.03
40	252.6	7.14	6.28
50	172.7	4.45	3.94
11 HRS	416.4	14.23	12.44
10	253.2	7.66	6.14
20	92.4	2.02	1.73
30	410.3	14.87	11.98
40	254.3	8.07	6.41
50	169.9	4.80	3.71
12 HRS	415.7	15.68	12.85
10	418.0	16.27	12.55
20	93.2	2.35	1.76
30	338.9	12.84	9.13
40	250.8	9.01	6.19
50	174.2	5.55	3.91
13 HRS	419.8	17.45	12.06
13 HRS	419.1	17.15	11.99
10	255.8	9.52	6.28
20	75.3	2.14	1.35
30	333.1	13.38	8.65
40	254.0	10.04	6.30
50	172.9	6.37	3.85
14 HRS	411.0	18.78	11.90
14 HRS	419.2	19.15	12.08
10	256.6	10.65	6.22
20	85.3	2.86	1.69
30	334.4	15.35	8.86

Date and Time: 02/21/2001 1:11:06 PM

WB	DB	RH
62	80	35%
61	75	44%

Date and Time: 02/22/2001 09:42:30 AM

WB	DB	RH
63	80	38%
60	74	44%

Date and Time: 02/22/2001 12:44:13 PM

WB	DB	RH
60	74	44%
64	80	42%
60	74	44%

Date and Time: 02/23/2001 10:01:40 AM

WB	DB	RH
60	72	50%

Date and Time: 02/23/2001 12:56:13 PM

WB	DB	RH
61	81	42%

TABLE 3: DONALDSON HMMWV PRODUCTION FILTER TABULAR DUST CAPACITY TEST RESULTS

SHEET 2 OF 3

40	251.3	10.67	6.13		65	81	42%
50	170.9	7.04	3.88				
15 HRS	418.2	21.05	12.35				
10	252.1	11.79	6.70				
20	82.0	3.21	1.62				
30	335.5	16.94	9.31				
40	252.8	12.43	6.19				
50	158.3	8.35	3.81				
16 HRS	415.7	22.75	11.91				

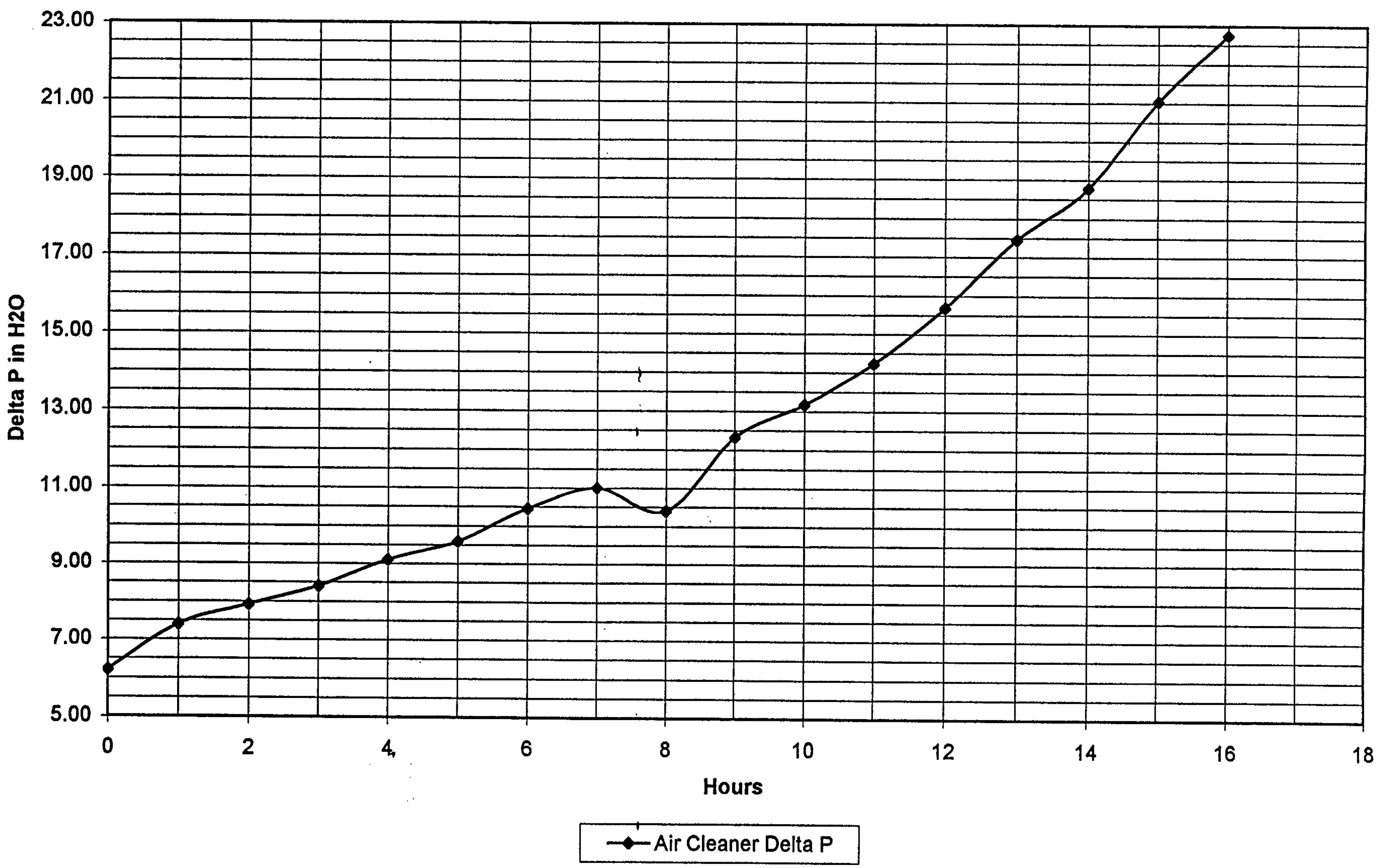
TABLE 3: DONALDSON HMMWV PRODUCTION FILTER TABULAR DUST CAPACITY TEST RESULTS

SHEET 3 OF 3

			Weightings and Calculations					
	Wt. Dust Feeder and Inlet Conductors						Before=	45755.5
Dust feeder, Dust, Dust Tray, Dust delivery hose, Inlet							After=	39708.0
piezometer tube, smooth approach nozzle, hose and hose							Dust fed=	6047.5
clamp.								
	Wt. Air Cleaner						After=	8851.0
Air cleaner housing, spacer hose, element, large clamp and							Before=	6741.0
scavenge dust collector jar with two hoses and two hose clamps.								2110.0
	Wt. Scavenge							
Scavenge dust collector jar with two hoses and one clamp								
After=	2914.0	After=	2921.5	After=	1521.0			
Before=	952.5	Before=	953.5	Before=	953.5			
	1961.5		1968.0		567.5			
	Total Dust Scavenged =			4497.0				
	Wt. Element						After=	3568.0
							Before=	2057.5
								1510.5
	Master filter element						After=	109.69
							Before=	108.79
								0.90
	Unaccounted Dust=		7.1					
	Pre-cleaner EFF=		74.36	%				
	Total Aircleaner Eff=		99.99	%				

TABLE 4: WEIGHTINGS AND CALCULATIONS FOR DONALDSON AIR FILTER

FIGURE 3: Capacity Test: Air Cleaner Delta P Vs. Hours @ 420 CFM (PAPER BASE PRODUCTION)



The Donaldson Production filter element service life of 14.5 hours to a 20 inches of water restriction across the air cleaner falls below the recommended 16 hour service life and is 5.5 hours below the current 20 hour service life requirement. The dust capacity is always measured in terms of grams of dust and Table 4 indicates that 6,047.5 grams of dust was fed for 16 hours. Every hour 378 grams of dust was fed based on a dust feed rate of .025 grams per cubic foot times the airflow rate for each 10 minute interval. Thus in 14.5 hours 5,480.5 grams of dust was fed. The precleaner efficiency was measured at 74.36% and the total aircleaner accumulative efficiency was 99.99% which exceeds the minimum requirement of 99.9%.

Table 3 provides a running tabulation of the time versus airflow, air cleaner delta pressure drop and master filter pressure drop. It is of interest to note that at each hour check point the airflow is not exactly at 420 cubic feet per minute. The rationale for this is that pressure transducers were used for airflow measurements and at the time the printout occurred the accuracy of pressure transducer would not provide an exact reading of 420 cubic feet per minute.

5.2.2 SPUNBOND POLYESTER FILTER ELEMENT

The prototype HMMWV spunbond polyester with expanded metal screen on intake side or dirty side and with 44.18 square feet of media material was dust capacity tested at a variable airflow rate. The step airflow cycle was ran to the same test methods and test procedures as the Donaldson Production filter element.

Test results are shown in Tables 5 and 6. A graphical presentation of test results is shown in Figure 4.

Test results showed the spunbond polyester filter element achieved a maximum service life of approximately 3.4 hours before reaching the required 20 inches of water restriction across the air cleaner. The air cleaner restriction is measured by piezeometer rings installed in the air cleaner duct before and after the air cleaner. The air cleaner restriction tap on the metal housing which is connected to an air cleaner restriction gauge is not considered as accurate a reading.

The 3.4 hours of service life is only ¼ of the service life obtained with Donaldson Production filter element and is 16.6 hours below the current 20 hour service life requirement. The dust capacity measured in terms of grams and shown in Table 6 indicates that 1509.0 grams of dust was fed for 4 hours which would correspond to 1357.8 grams of dust being fed in 3.4 hours. Thus, the spunbond filter element only had ¼ of the dust fed in comparison to the Donaldson Production filter element (1357.8 grams vs 5480.5 grams). The differential between service life and amount of dust fed for the two filter elements provides a good correlation. Table 6 also shows precleaner efficiency was measured at 74.62% and the total accumulative efficiency was 99.94% which exceeds the minimum requirement of 99.9%.

Table 5 provides a running tabulation of the time versus airflow, air cleaner delta pressure drop and master filter pressure drop. The test data shows the air cleaner pressure

Title: Capacity Test #2
Comment: Sponbond Element
Date and Time: 02/28/2001 2:30:11 PM
Orifice Areas= 0.055905 C Constant= 0.99

Time	Airflow SCFM	Aircleaner Delta	Master Filter Delta
0	421.4	5.49	13.08
10	235.8	2.40	6.82
20	83.1	0.38	1.88
30	342.5	4.35	9.81
40	251.4	2.72	6.47
50	168.0	1.57	4.24
1 HR	419.8	8.75	13.96
1 HR	418.0	8.92	14.52
10	255.4	4.29	6.79
20	96.5	0.72	2.00
30	330.0	8.13	9.77
40	249.1	5.44	7.09
50	177.8	2.69	4.36
2 HRS	417.0	14.07	13.70
10	256.0	6.81	7.23
20	99.8	1.00	1.93
30	345.0	11.57	10.42
40	258.4	7.57	7.17
50	175.4	4.17	4.43
3 HRS	419.7	18.38	14.48
10	259.0	8.90	6.66
20	91.7	1.23	1.73
30	340.9	14.36	9.84
40	258.5	9.47	6.56
50	177.5	5.28	4.28
4 HR	417.8	22.72	14.22

WB	DB	RH
59.0	73	43%

Date and Time: 03/01/2001 1:01:06 PM

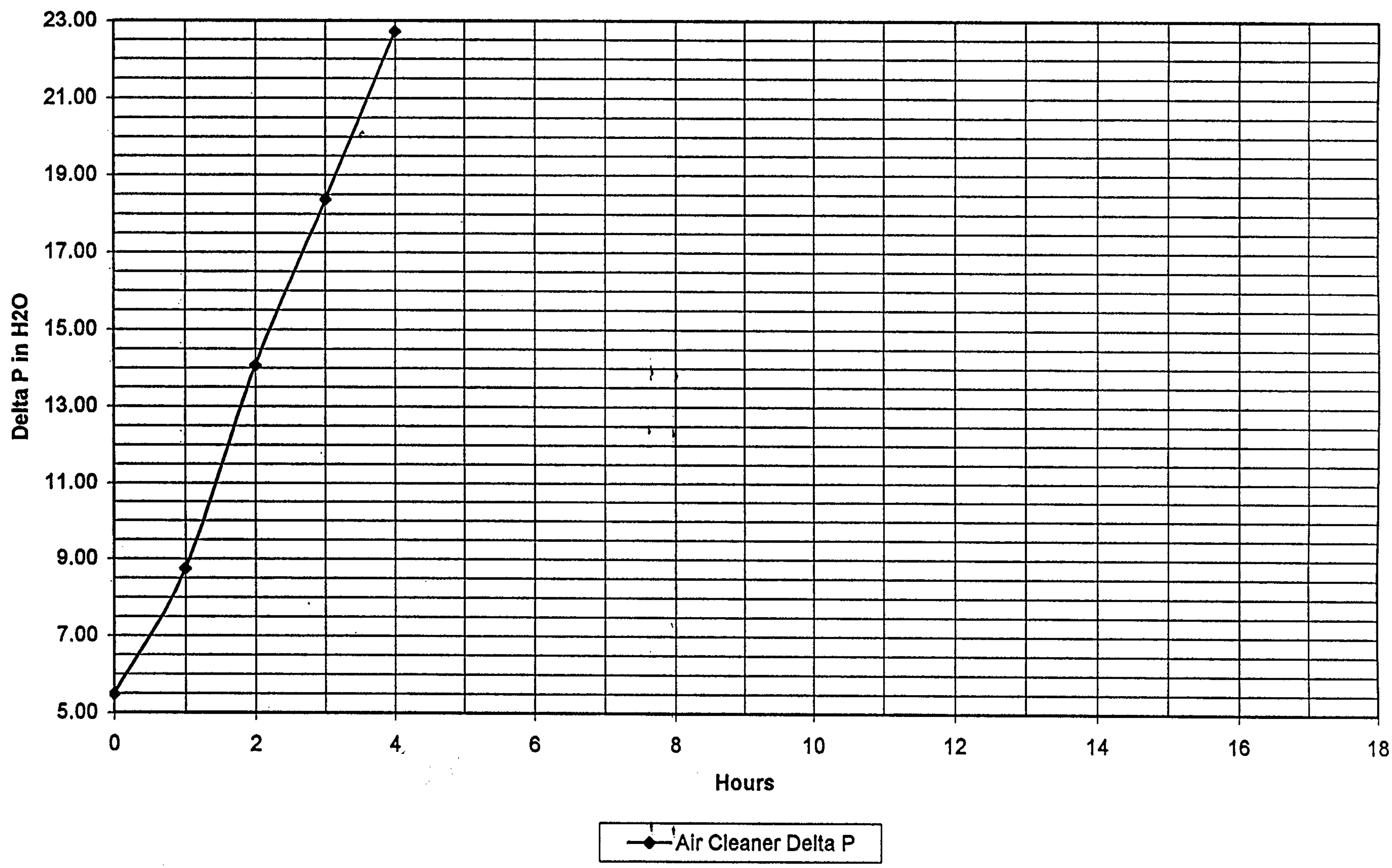
WB	DB	RH
64	79	44%
65	79	47%

TABLE 5: SPUNBOND POLYESTER HMMWV PROTOTYPE FILTER TABULAR DUST CAPACITY TEST RESULTS

Weightings and Calculations		
Wt. Dust Feeder and Inlet Conductors	Before=	44313.5
Dust feeder, Dust, Dust Tray, Dust delivery hose, Inlet piezometer tube, smooth approach nozzle, hose and hose clamp.	After=	42804.5
	Dust fed=	1509.0
Wt. Air Cleaner	After=	8997.0
Air cleaner housing, spacer hose, element, large clamp and scavenge dust collector jar with two hoses and two hose clamps.	Before=	7489.0
		1508.0
Wt. Scavenge	After=	2078.5
Scavenge dust collector jar with two hoses and one clamp	Before=	952.5
		1126
Wt. Element	After=	3174.5
	Before=	2805.5
		369
Master filter element	After=	108.72
	Before=	107.79
		0.93
Unaccounted Dust= 0.1		
Pre-cleaner EFF= 74.62 %		
Total Aircleaner Eff= 99.94 %		

TABLE 6: WEIGHTINGS AND CALCULATIONS FOR SPUNBOND POLYESTER AIR FILTER

FIGURE 4: Capacity Test : Air Cleaner Delta P Vs. Hours @ 420 CFM (SPUNBOND)



drop for the spunbond filter element increases many times to that of the Donaldson Production filter element for every hour of testing.

6.0 CONCLUSIONS/RECOMMENDATIONS

1. The HMMWV prototype spunbond polyester filter elements are not considered to have sufficient dust capacity and/or service life when tested to MIL-PRF-46736E. The service life is only 25% of the standard production HMMWV filter element. (3.4 hours for spunbond versus 14.5 hours for production filter element, as compared in Figure 5).

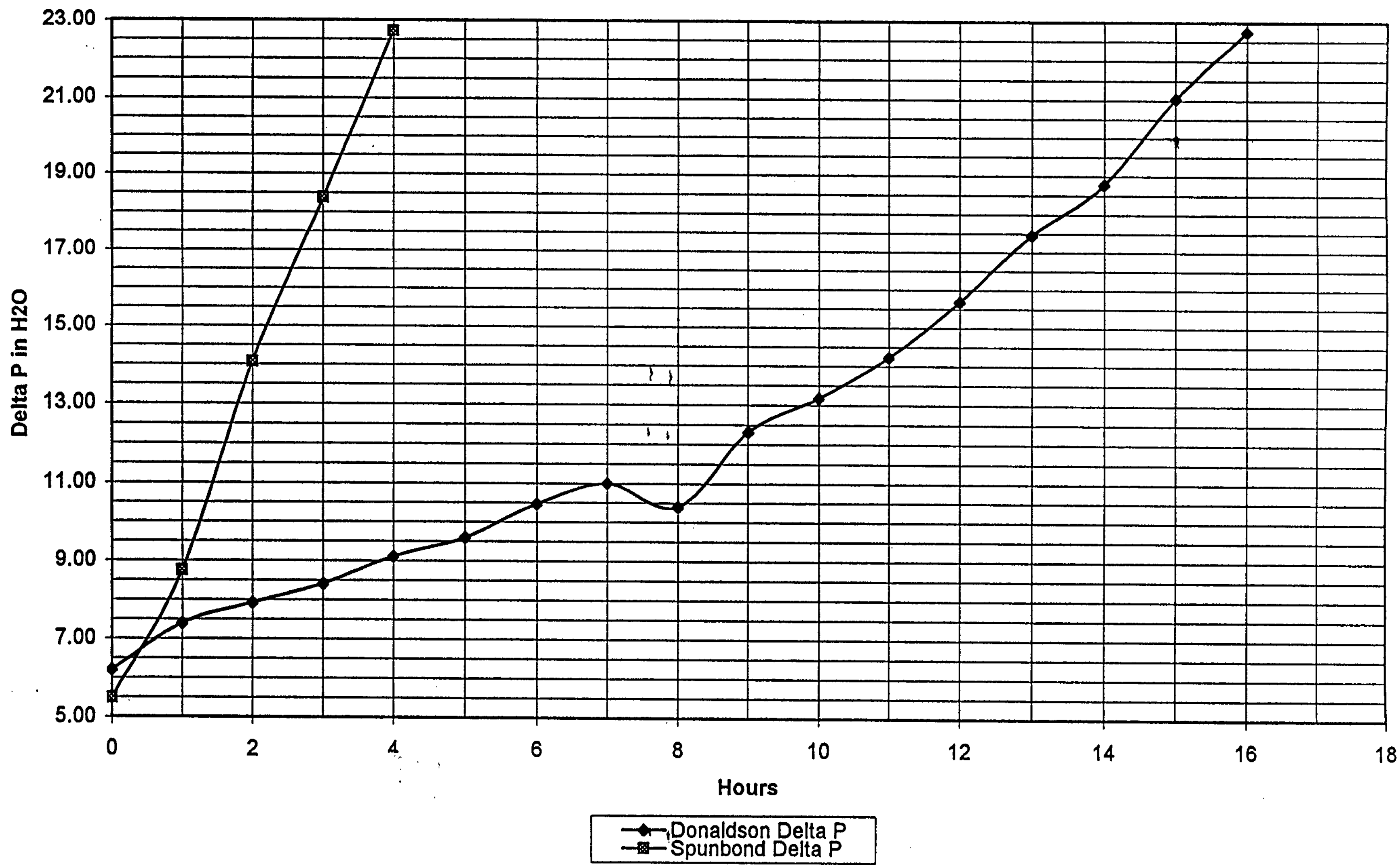
2. The HMMWV prototype spunbond polyester filter element met MIL-PRF-46736E initial efficiency requirement of 99.5%. The efficiency test was ran for 60 minutes versus the intended 30 minutes. A 30 minutes initial efficiency test is specified when the face velocity is 6 ft/min or less. The HMMWV prototype spunbond filter element used in initial efficiency test had 39.84 square feet of media area and a corresponding face velocity of 9.50 ft per minute.

3. The Donaldson Production filter element was designed with pleat lock that provides controlled spacing between the pleats. The pleat spacing was not as controlled or spaced equally on the prototype spunbond polyester filter element. In addition, the Donaldson Production filter element had 53.72 square feet of media area whereas one spunbond polyester filter element (with no expanded metal or intake) had 39.84 square feet of media area and the other (with expanded metal on intake) had 44.18 square feet of media area. This represent 21.6% and 38.8% respectively more filter area for the Donaldson filter compared to the two spunbond filters. Also, this represents a 10.8% difference in square feet of media area between the two spunbond filters.

The lower square feet of media area in spunbond filters surely accounts for some difference in reduced service life and dust holding capacity from the Donaldson filter. However, it is believed that if the square feet of media area of spunbond were equal to the Donaldson Production filter there would still be a significant difference in service life. The uneven spacing of pleats in spunbond filter also may make a small contribution in difference of service life to that of Donaldson filter.

4. It is recommended that an air cleaner test program be initiated to investigate the affects of vibration on filter element dust capacity and service life. A pilot program should be conducted to measure vibration on air cleaner housing (of say a HMMWV) over typical vehicle mission profile that includes idling, cross country, improved road and highway driving. Record the vibration levels and then apply these vibration levels to a specified schedule on the air cleaner housing during filter element lab testing per MIL-PRF-46736E. Validate if dust capacity and/or service life and efficiency is increased or decreased. This application is currently being applied to engine oil and fuel filters and needs to be evaluated on air cleaners. This could possible increase the service life for spunbond polyester filter elements.

FIGURE: 5 Capacity Tests: Air Cleaner Delta P Vs. Hours @ 420 CFM (COMPARISON)



APPENDIX A

SPUNDBOND POLYESTER PRODUCT SPECIFICATION AND SUPPLIER COMMENTS

HOLT DISTRIBUTING & MANUFACTURING CO.
2246 S. Railroad
Fresno, CA 93721
Telephone: (559) 266-8349 or (800) 350-4658
Facsimile: (559) 266-2236

SPUNBOND POLYESTER

HD-227L PRODUCT SPECIFICATION

HD-227L is a non-woven spunbond polyester, renewable media. This media combines high efficiency, excellent release characteristics with its moisture tolerance to give you a high volume, extended life filter.

Color	:	White
Weight	:	8.1 oz/sq yd.
Heat	:	275°F, 200°F standard construction
Moisture Tolerance	:	Excellent, media is washable
Abrasion Resistance	:	Excellent, 5-7 x stronger than cellulose
Dust Release Traits	:	Excellent cleaning and release properties
Air Permeability	:	28-33 CFM/sq. feet at ½ " WG
Efficiency*	:	Up to 99.995 @ .2 – 2 microns
BIA Rating	:	U, S, G & C

The HD-227L media can be manufactured with these special features:

1. Hydro and Olieo Phobic finish for your oil mist applications
2. High heat construction to 275°F
3. PTFE membrane for those fine dusts
4. Anti-static finishes or carbon fiber construction
5. Dust-Free or Pleated Bag design
6. Environmental construction

Specifications may change without notice

**Efficiencies will vary depending on application.*

HOLT DISTRIBUTING & MANUFACTURING CO.
2246 S. Railroad
Fresno, CA 93721
Telephone: (559) 266-8349 or (800) 350-4658
Facsimile: (559) 266-2236

100% Non-Woven Spunbond Polyester Media for Cartridge Filters

PROPERTY	VALUE
Style	HOLT MFG.
Fiber	100% Spunbond Polyester
Weight	8.45 ounce/yd^2
Construction	Non-woven, spunbond
BIA Rating	U,S & G
Air Permeability	28 cfm @ ½" w.c.
Mullen Burst	387 psi
Tensile Strength	219 lbs X-Direction 225 lbs Y-Direction
Thermal Stability	2% Maximum @ 275°F
Max Operating Temperature	275°F for base media, finished elements maximum temp. rating is 200°F. Higher temperature construction available.
Finish	Calendared, heat-set
Optional Finishes	■ PTFE Laminate ■ Aluminized for Anti-Static Ground ■ Oil/Water Repellant
Resistance Ratings	See Table at Right →

TYPICAL MEDIA PROPERTIES

This data is to be considered as typical, and for information purposes only. All specifications are subject to change.

Resistance Ratings (base media) Chart

Reagent	A	B	C	D
Acids			●	
Alkalis		●		
Oxidants		●		
Solvents		●		
Hydrolysis			●	
Abrasion	●			

Combinations of chemicals may alter fiber resistance to the specified performance level.

A = Excellent D = Fair

APPLICATION: Many industrial process, nuisance, and pneumatic conveying applications. HD-227L media is characterized by high filtration efficiencies of fine particulate, and very good dust release properties. Suitable for fibrous materials, such as wood and fiberglass. A good choice for dust streams containing coarser sized particles.

Maximum penetration degree of the filter material for inserting in devices with the following classifications:

DEVICE CLASSIFICATION	PURPOSE OF USE	MAXIMUM ALLOWED PENETRATION DEGREE
-U	Separation of dust with MAK-value of 1 mg/m3	5%
-S	Separation of dust with MAK-value of 0,1 mg/m3	1%
-G	Separation of dust with MAK-values	0.5%
-C	Separation of dust with MAK-values and of cancer-producing substances of group 2, 3	0.1%
-K1	Separation of dust with MAK-values and of cancer-producing substances of group 1, 2, 3	0.05%
-K2	Separation of dust with illness-producing substances (e.g. virus or germ)	0.05%

The HD-227L, HD-227L-HO, HD-227L-AL and HD-227TM Series Medias carry the U, S, G & C BIA ratings.

Classification U, S, G & C

The test is carried out on new filter material.

The filtration velocity during the test is 0.056 m/s.

Quarzdust with a concentration of (200 +/- 20) mg/m3 is used for this test.

About 90% of the particle number of the test lies between 0.2 um and 2 um on average according to Stoke.

*MAK → Maximum working area concentration

Margrif, Frank

From: Lucia Hubbard [wgntails@kvalley.com]
Sent: Sunday, December 10, 2000 7:33 PM
To: margriff@tacom.army.mil
Subject: spunbond

skipsnw@aol.com

Frank,
This message regards the two engine air filters I sent you via UPS; They fit the HMMWV family of vehicles. The NSN of their ³conventional² counterpart is 2940-01-188-3776.

From our last telephone conversation it is my understanding that both air filters will be subjected to two lab tests; one for filtering efficiency, and one for ³service life².

Both filters have been remanufactured from used HMMWV end caps and have a Œspunbond¹ polyester media installed. The filter that has no outer expanded metal screen contains Œspunbond¹ media that has been ³dimpled², this dimpling gives the media added lateral strength which is important in preventing Œpleat bunching¹ which happens when the filter is over loaded with dust and other particulate matter.

What we and Jess Holt are particularly impressed with is the extraordinary strength and durability of the spunbond media. Our experience in the commercial sector and with the HMMWV spunbond filter being field-tested at Fort Lewis is that filters using spunbond media can be Œcleaned¹ numerous times over a very long period of time in the field. This assumes inexperience servicing people using the most aggressive cleaning methods available to them; the filter media simply will not fail or be degraded significantly.

The cost of the two prototype test air filters is $100.00 each.

We are most interested in any comments you or your colleagues may have regarding these two filters.

Regards,

Dave Hubbard

APPENDIX B

LABORATORY ANALYSIS

OF PAPER MEDIA PROPERTIES

AHLSTROM FILTRATION

AHLSTROM FILTRATION, INC.

P.O. Box 2009 • 105 West 45th Street
Chattanooga, Tennessee 37409

Telephone (615) 821-4090
Fax (615) 821-2300

SAMPLE SHIPMENT NOTICE

TO: Jess Holt

FROM: T. L. Bak

1. Sample ~~No. OS~~ 9N-6
2. Date Shipped 2/26/91
3. Sent to (Company) Holt
4. Means of Shipment truck
5. No Rolls or Sheets Order
6. Mill or Reel No.
7. Sample Slit Size various
8. Paper Type No. 9N-6 (white)
9. Description Average Run Data, 9N-6, Lot 210827

LABORATORY ANALYSIS

	This Sample ☐	AIM Values ☐
1. Basis Wt., lbs./3000 sq.ft., Treated (Uncured, Cured)	85.0	
2. Caliper, mils ☐ Ames ☐ Optical ☐ TMI	17.0	
3. Corrugation Depth, mils	14.5	
4. Frazier Air Flow, cfm. per sq. ft. @ ½" Water Diff. Pressure	23.2	
5. Maximum Pore Size (Bubble Point) Pressure, Inches Water ☐ 99% ISO ☐ AC 394 ☐ 1st Bubble ☐ 3rd Bubble	7.1	
6. Mean Flow Pore Size, (Assoc. Amer. RR Test), microns	17.5	
7. Resin Type: Non-cure % by weight	18.7	
8. Volatiles %	7.4	
9. Dry Mullen Burst, psi (Uncured, Cured)	48.0	
10. Wet Mullen Burst, psi (Uncured, Cured)	33.0	
11. Uncured Stiffness, mgs. M.D.	4000	
12. Cured Stiffness, mgs. M.D./C.D.	5000	
13. Tensile, lbs./in. M.D. (Uncured, Cured)		

FILTRATION SCIENCES
CORPORATION
Southern Specialty Division

SAMPLE SHIPMENT NOTICE

TO: Mr. Jess Holt FROM: Bill Reynolds

1. Sample No. OS- -
2. Date Shipped --
3. Sent to (Company) Holt Distributing
4. Means of Shipment --
5. No Rolls or Sheets --
6. Mill or Reel No. --
7. Sample Slit Size --
8. Paper Type No. 9P-40 (TAN)
9. Description Grade 9P-40 Heavy Duty Air Filter Paper

LABORATORY ANALYSIS

	This Sample ☐	Typical ~~AIM~~ Values ☒
1. Basis Wt., lbs./3000 sq. ft., Treated (Uncured, Cured)		91
2. Caliper, mils ☒ Ames ☐ Optical ☐ TMI Flat		22
3. Corrugation Depth, mils		15
4. Frazier Air Flow, cfm. per sq. ft. @ ½" Water Diff. Pressure		28
5. Maximum Pore Size (Bubble Point) Pressure, Inches Water ☐ 99% ISO ☒ AC 394 ☒ 1st Bubble ☐ 3rd Bubble		7
6. Mean Flow Pore Size, (Assoc. Amer. RR Test), microns		16
7. Resin Type: Standard Phenolic % by weight		20
8. Volatiles %		7
9. Dry Mullen Burst, psi (Uncured, Cured)		35
10. Wet Mullen Burst, psi (Uncured, Cured)		30
11. Uncured Stiffness, mgs., M.D.		3000
12. Cured Stiffness, mgs. M.D./C:D.		5500
13. Tensile, lbs./in. M.D. (Uncured, Cured)		

cc: Sample Book, Sales, FKK, RLG, CPC

APPENDIX C

REQUEST FOR OIL ANALYSIS RECORDS ON HMMWV ENGINE NO. 044494E

Fax

SKIP'S NW FILTER SERVICE
P.O. Box 515
Ellensburg, WA 98926
Tel/Fax (509) 925-4888
Cell No. 509-899-0042

DATE	9 June 1999
TO	Mr. Frank Margrif (AMSTA-TR-R)
	U.S. Army Tank Automotive Command, Warren, Michigan
FAX NUMBER	(810) 574-5054
FROM	Dave Hubbard.

MESSAGE

Dear Frank,

I enjoyed our telephone conversation last week about air filter cleaning; Hope we can get together some time and hash out the subject from end to end. It's a subject that's a lot like politics; for some reason everybody is an "expert".

The purpose of this FAX, however, is to ask for your help in obtaining oil analysis lab data.

Jess Holt (owner of Holt Distributing) and I have taken the metal components from two HMMWV engine air filters and reassembled them using the 'Spunbond' air filter media which we discussed with you at the Fort Lewis meeting last November. As I recall, Jess gave you a specification sheet which showed, among other things, the filtering efficiency of the Spunbond media. I expect that you have access to other media specs so you can verify that the efficiency of the Spunbond media is a bit higher than 'conventional' media.

A Fort Lewis unit, the 1-32AR, an M1 unit belonging to the 3RD Armored Brigade, is scheduled to deploy to the Yakima Training Center near the end of July for a couple of months. I've coordinated with the Battalion Motor Officer and Motor Tech. A HMMWV "owned" by them will be used extensively in extremely dusty conditions throughout the deployment. What we'd like to do is service test our Spunbond HMMWV engine air filters on their vehicle during the upcoming deployment. Jess Holt and I are more than confident that the exceptional durability of the Spunbond media combined with its very high filtering efficiency will be a real eye opener.

The Yakima Training Center is only 35 miles from my home and I am in that area every two weeks, so monitoring the testing will be no problem.

In order to establish a track record and for comparison purposes we would like to have access to the historical oil analysis records for the vehicle as well as the results of the ongoing Fort Lewis oil analyses for the vehicle. I talked to Mr. Ray French who runs the oil analysis program at Fort Lewis: He said that to have oil analysis data I needed to ask "TACOM" to request that the Program Director (Mr. John Dixon), Army Oil Analysis Program Director at the Redstone Arsenal in Huntsville provide me with the information. From the data on each oil analysis I can pick off the Silica count which is my primary interest.

Jess Holt and I will provide the air filters and track their performance and keep you fully informed. As I mentioned to you in our telephone conversation there would be no charge to the Army for any of this work. If these air filters perform, in every respect, like we firmly believe they will, the Army can anticipate savings through fewer engine failures due to dust injestion and, quite possibly, extended oil service life times.

I ask for your help in obtaining the oil analysis data I've talked about in this letter.

The specifics on the vehicle:

"Bumper NO." HQ81 NG377V
'ENDITEM' NO. for the engine: 044494E

Please call me with any questions you may have, or to ask for additional information.

Thanks again for your time and attention.

Dave Hubbard

David B. Hubbard

APPENDIX D

ARMY OIL ANALYSIS PROGRAM (AOAP)

RECORDS ON HMMWV ENGINE NO. 044494E

ARMY OIL ANALYSIS PROGRAM (AOAP)
OIL ANALYSIS STANDARD INFORMATION SYSTEM (OASIS)
DATA DICTIONARY
(Extract)

ELEMENT NAME   DEFINITION
-------------- -----------------------------------

AG - Silver: Spectrometric findings for the element silver contained in the lubricant analyzed and shown in parts per million (PPM).

AL - Aluminum: Spectrometric findings for the element aluminum contained in the lubricant analyzed and shown in parts per million (PPM).

ALKLIN - Alkalinity: Results of test for lubricant alkalinity.

ANOX - Anti-oxidant reading value

ANOXCR - Anti-oxidant Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

AW - Anti-wear reading value

AWCR = Anti-wear Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

B - Boron: Spectrometric findings for the element boron contained in the lubricant analyzed and shown in parts per million (PPM).

BKDN - Ester Breakdown reading value

BKDNCR - Ester Breakdown Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

BKD2 - 2nd Ester Breakdown reading value

BKD2CR - 2nd Ester Breakdown Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

COMPMOD - Component Model: Type, model, and series component.

COMPSN - Component Serial Number: Unique serial number assigned to the enrolled component or system, e.g., engine, gearbox, etc.

CONTAM - Contaminants: Results of tests to measure amount of insoluble present in lubricants analyzed.

COOL - Coolant: Results of tests to determine the presence and amount of coolant in lubricants. (XX.X or P=Pass, F=Fail)

COOLF -Coolant FTIR: Optimized Ethylene Glycol reading value

COOLFCR - Coolant FTIR Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

CR - Chromium: Spectrometric findings for the element chromium contained in the lubricant analyzed and shown in parts per million (PPM).

CRACKLE - Lubricant test for water contamination. Results are P (pass) or F (fail).

CU - Copper: Spectrometric findings for the element copper contained in the lubricant analyzed and shown in parts per million (PPM).

DIES - Diesel Dilution reading value

DIESCR - Diesel Dilution Flag: Computer reading flag, i.e. L = low, N = normal, or H = high

DISPERS - Dispersants: Results of test to determine the dispersant ability of lubricants analyzed.

EIMOD - End Item Model.

EISN - End Item Serial Number: Unique serial number assigned to the equipment end-item on which the enrolled component is installed.

EPWA - Water in EP additive fluids reading value

EPWACR - EP Water: Computer reading flag, i.e., L = low, N = normal, or H = high

FE - Iron: Spectrometric findings for the element iron contained in the lubricant analyzed and shown in parts per million (PPM).

FUEL - Fuel dilution reading value

FUELCR - Fuel Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

FUELDIL - Fuel Dilution: Results of physical property test to determine the presence of diesel fuel or gasoline. (XXX)

GAS - Gasoline: Gasoline dilution reading value

GASCR - Gasoline Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

HRSCOMP - Hours Component: The number of component operating hours since the component was new or since the last time the component was overhauled.

HRSOIL - Hours Oil: Number of component operating hours since the last time the oil in the component was changed.

INSOL - Insoluble: Results of test for insoluble.

IRCOMPREC - Fourier Transform Infra-red Computer Recommendation

JP - JP5/JP8/Diesel Dilution reading value

JPCR - JP Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

LABCODE - Laboratory Code: Unique laboratory identification code that includes military service and major Army command.

MAJCOM - Major Command: Joint Oil Analysis Program code of the customer units major command.

MEAS - Measure: The unit of measure (P=pints, Q=quarts, or G=gallons) for the number entered in the OIL data field.

METHOD - Method Number: Identification number of FTIR method used to evaluate the sample.

MILEAGE - The odometer or hour meter reading of the equipment end-item on which the enrolled component is installed when the oil sample was taken.

MG - Magnesium: Spectrometric findings for the element magnesium contained in the lubricant analyzed and shown in parts per million (PPM).

MO - Molybdenum: Spectrometric findings for the element molybdenum contained in the lubricant analyzed and shown in parts per million (PPM).

NA - Sodium: Spectrometric findings for the element sodium contained in the lubricant analyzed and shown in parts per million (PPM).

NI - Nickel: Spectrometric findings for the element nickel in parts per million (PPM).

NITR - Nitration reading value

NITRCR - Nitration reading value flag: Computer reading flag, i.e., L = low, N = normal, or H = high

OIL - The amount of oil that has been added to the component lubricant system since the last oil change. (NOTE: Unit of measure shown in MEAS)

OILTYPE - Type of oil the tested component is serviced with.

OTHR - Other: Other fluid contamination in synthetic lubricant.

OTHRCR - Other Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

OXID - Oxidation reading value

OXIDCR - Oxidation Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

PB - Lead: Spectrometric findings for the element lead contained in the lubricant analyzed and shown in parts per million (PPM).

REMARKS - Technical narrative supplement entered by laboratory personnel.

SAMPNO - Sample Number: A unique number assigned by the AOAP laboratory for internal tracking.

SAMPDATE - Sample Date: Date sample taken.

SI - Silicon: Spectrometric findings for the element silicon contained in the lubricant analyzed and shown in parts per million (PPM).

SN - Tin: Spectrometric findings for the element tin contained in the lubricant analyzed and shown in parts per million.

SOOT - Soot value reading value

SOOTCR- Soot Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

SULF - Sulfate: Sulfate by-products reading value

SULFCR - Sulfate Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

TEC - Type Equipment Code: A code that identifies the type, model, and series of the enrolled component and the model, design, and series of the end item in which it is installed.

TEMP - Temperature: Temperature at the time oil sample was tested. (XXX or 782 = 78.2 degrees F)

TI - Titanium: Spectrometric findings for the element titanium contained in the lubricant analyzed and shown in parts per million (PPM).

UIC - Unit Identification Code: Standard unit identification code of the unit or organization to which the component is assigned.

VISC - Viscosity: Numerical rating from physical property test to determine viscosity of the lubricant analyzed.

WATR - Water: Water in EP additive fluids reading value

WATRCR - Water Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

WA2 - Water 2: Total hydroxyl (water &/or Brkdwn) reading value

WA2CR - Water 2 Flag: Computer reading flag, i.e., L = low, N = normal, or H = high

ZN - Zinc: Spectrometric findings for the element zinc contained in the lubricant analyzed and shown in parts per million (PPM).

Full_Record

UIC	TEC	COMPSN	COMPMOD	EISN	EIMOD	SAMPNO	SAMPDATE	LABCODE	MILEAGE	HRSCOMP	HRSOIL
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	03680	2/29/96	A4L	39448	999999	9999
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	02204	8/9/96	A4L	40866	999999	9999
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	00435	1/30/97	A4L	57309	5730	5730
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	03704	7/16/97	A4L	5571	999999	9999
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	01227	12/31/97	A4L	7036	703	703
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	02110	1/13/98	A4L	7123	712	712
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	04388	2/19/98	A4L	7182	770	770
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	01598	9/9/98	A4L	12189	1270	1270
WC01T0	BBDA	044494E	6.2 L DIESEL	44494	M998	03973	3/18/99	A4L	14000	1399	1399

Full_Record

OIL	MEAS	FE	AG	AL	CR	CU	MG	NA	NI	PB	SI	SN	TI	B	MO	ZN	REMARKS	CRACKLE	VISC
0		33	0	5	5	3	33	3	1	8	7	0	0	66	106	237		P	192
1	Q	111	0	7	22	5	239	70	3	12	16	6	0	81	103	673		P	174
0		210	0	11	32	10	312	67	6	24	23	11	0	63	95	460		P	204
0		196	0	19	31	14	199	34	4	89	25	30	0	52	118	601		P	170
1	Q	42	0	5	7	6	28	8	0	15	74	1	0	121	119	448	??	P	149
999		43	0	4	7	6	24	6	1	12	74	5	0	99	163	911		P	142
0		51	0	5	12	8	27	9	1	18	74	1	0	90	105	464		P	133
0		114	0	11	16	9	28	9	3	28	48	3	0	86	141	355		P	170
999		109	0	10	13	8	26	8	1	26	36	8	0	88	127	514		P	150

FUELDIL	TEMP	CONTAM	COOL	DISPERS
0	74	2	1	1
0	74	2	1	1
0	71	2	1	1
0	73	2	1	1
0	73	2	1	1
	71	2	1	1
0	74	2	1	1
	72	2	1	1
	71	2	1	1

rowno	ppmrangtyp	fe	ag	al	cr	cu	mg	na	ni	pb	si	sn	ti	b	mo	zn	dt_revis
83	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21-Jan-97
83	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21-Jan-97
83	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21-Jan-97
83	4	500	0	50	45	400	0	50	0	115	90	90	0	20	40	0	21-Jan-97
83	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21-Jan-97

APPENDIX E

SOUTHWEST RESEARCH INSTITUTE (SwRI)

LAB TEST OF HMMWV FILTER ELEMENTS

FROM TWO (2) DIFFERENT SUPPLIERS

ATTACHMENT I

SOUTHWEST RESEARCH INSTITUTE
TESTING 420 CFM ELEMENT
FROM TACOM FILTER HOUSING

SOUTHWEST RESEARCH INSTITUTE

6220 CULEBRA ROAD • POST OFFICE DRAWER 28510 • SAN ANTONIO, TEXAS, USA 78228-0510 • (210) 684-5111 • TELEX 244846

ENGINE AND VEHICLE RESEARCH DIVISION
FAX: (210) 522-5720

December 17, 1996

Ms. Cecila Ewing
International Filter Manufacturing
402 West Ryder
P. O. Box 549
Litchfield, Illinois 62056

VIA FACSIMILE TO (217) 324-2390 AND FIRST CLASS MAIL

Subject: Southwest Research Institute Project No. 03-7612-022, "Air Filter Testing"

Dear Ms. Ewing:

This report presents results of airflow restriction, efficiency and dust capacity tests conducted on NSF 2940-01-188-3776 (M998 Utility Truck) air filter elements provided by International Filter Manufacturing (IFM) for evaluation. IFM A-D53 and TACOM elements marked 420CFM were tested. Testing was conducted in accordance with Military Specification MIL-F-46736C(AT) 12 April 1991, and the SAE J726 JUN93 Air Cleaner Test Code. Initial restriction (pressure drop), initial and cumulative efficiency, and dust capacity were measured. The cumulative efficiency/dust capacity tests were conducted to the variable flow schedule given in MIL-F-46736C Figure 1, with rated flow (100%) set at 420 scfm (27°C; 76 cm HG), using PTI SAE Coarse Dust (Batch 4440C) fed at a constant rate of 6.30 g/min. The initial efficiency test was run for thirty (30) minutes at rated flow (420 scfm) using PTI SAE Fine Test Dust (Batch 4555D) at a concentration of 0.883 g/m^3 air (0.025 g/m^3 air). Particle size data for the test dusts are given in Attachment 1. Testing was conducted with the element installed in a TACOM (GFE) NSF 2940-01-188-5117, P/N 19207-12339911 (MFR 34623, 03/05/96) multi-stage housing. The filter elements were inspected for structural integrity and quality of gaskets and seals before and after testing.

The test sequence was as follows: measure initial restriction (pressure drop) as a function of airflow rate for each element, conduct initial efficiency test (IFM A-D53 element #1 only) and cumulative efficiency tests (IFM A-D53 element #2 and American General element #1) while measuring dust capacity to 20 inches of water terminal pressure drop across the element and housing at rated flow.

Test results are presented in Table 1 and Figures 1 and 2. Table 1 give initial restriction (pressure drop) at 420 scfm, initial and cumulative efficiency, and dust capacity. Figure 1 shows initial restriction (pressure drop) across the assembly (element and housing) as a function of airflow rate. Two curves are given for each element: pressure drop as measured between the upstream and downstream peizometers, and pressure drop as measured between the upstream and downstream housing taps.

Figure 2 shows pressure drop (between the upstream and downstream housing taps) as a function of dust fed to the element and housing. Dust capacity in Table 1 represents the amount of dust fed to the assembly (element and housing) at a terminal pressure drop of 20 inches of water across the assembly, as measured between the upstream and downstream housing taps at rated flow. There were no leaks at the seals or at the plastisol-media interfaces, for any of the elements. There was, however, one leak through the media, located approximately 3 inches from the open end of the element, 5 inches clockwise from the inside seam, for the American General element.

If you have any questions concerning the test results or the project, please do not hesitate to call me at (210) 522-2626. For your convenience, our facsimile number is (210) 522-5720. Southwest Research Institute is pleased to have been of service, and we look forward to working with you again in the future.

Sincerely,

Martin B. Treuhaft

Martin B. Treuhaft
Manager
Filtration and Fine Particle Technology
Department of Vehicle Systems Research

/lc

d:\wpfiles\mbt\7612-022.822\$ pgs.

Attachments

Approved:

Gary L Stecklein

Gary L. Stecklein
Director
Department of Vehicle Systems Research

TABLE 1

INITIAL RESTRICTION (PRESSURE DROP), INITIAL AND CUMULATIVE EFFICIENCY, AND DUST CAPACITY: IFM A-D53 AND TACOM NSN 2940-01-188-3776 (M998 UTILITY TRUCK) FILTER ELEMENTS TESTED IN TACOM (GFE) 12339911 HOUSING; PTI SAE COARSE DUST (BATCH 4440C) @ 0.025 G/FT^3 AIR, EXCEPT FOR INITIAL EFFICIENCY (PTI SAE FINE DUST FOR 30 MINUTES); AIR FLOW RATE: 420 SCFM; IFM ELEMENTS MANUFACTURED OCTOBER 1996, TACOM 420 CFM ELEMENT PROVIDED AS GFE

ELEMENT	PLEAT COUNT	EXPOSED AREA, FT^2	INITIAL ΔP,* "H_2O	INITIAL** EFFICIENCY, %	CUMULATIVE** EFFICIENCY, %	DUST*** CAPACITY, G (HOURS)	COMMENTS
IFM A-D53 (1)	261	73.41	2.30 (8.00)	99.5	N/A	N/A	No Leaks
IFM A-D53 (2)	260	73.13	2.30 (8.00)	N/A	99.97	6172 (16.5)	No Leaks
TACOM 420 CFM (1)	259	70.15	2.35 (7.45)	N/A	99.97	6974 (18.4)	One Dust Leak Through Media

Elements Tested October 1996

* At rated flow (420 scfm) in housing, as measured between up and downstream housing taps and (between up and downstream piezometers).

$$** \quad \text{Efficiency} = \left[1 - \frac{\text{wt. gain of absolute}}{\text{wt. of dust fed}}\right] \times 100$$

*** At 20 inches of pressure drop across the element and housing, as measured between up and downstream housing taps, at rated flow; airflow schedule per Figure 1 of MIL-F-46736C.

CLEAN ELEMENT PRESSURE DROP AS A FUNCTION OF AIRFLOW RATE
NSF 2940-01-188-3776 (M998 UTILITY TRUCK) FILTER
ELEMENTS TESTED IN TACOM (GFE) 12339911 HOUSING

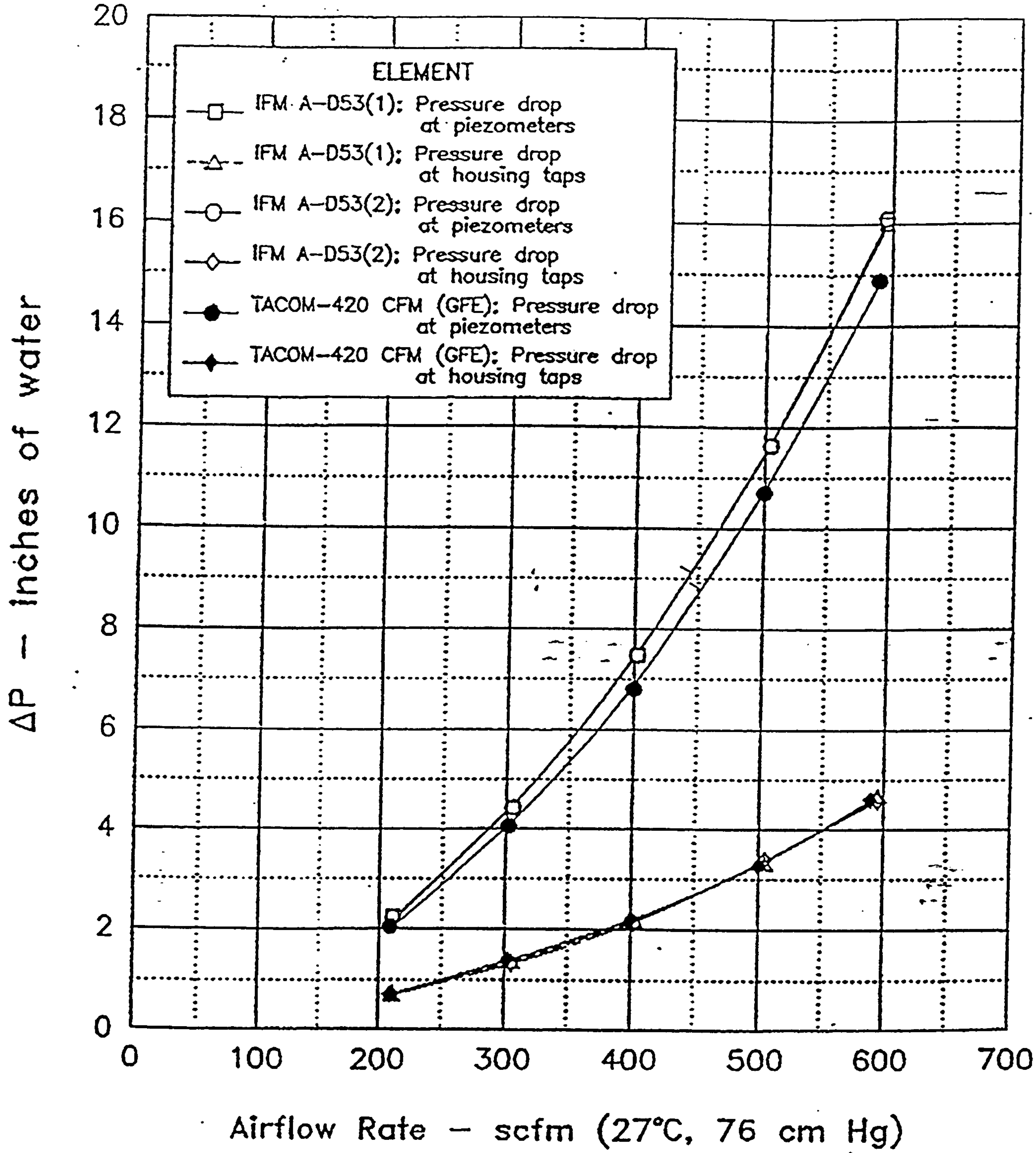


FIGURE 1

INTERNATIONAL FILTER MFG.

SWRI
10/96
MBT
P560

PRESSURE DROP AS A FUNCTION OF AIRFLOW TEST TIME
NSF 2940-01-188-3776 (M998 UTILITY TRUCK) FILTER
ELEMENTS TESTED IN TACOM (GFE) 12339911 HOUSING

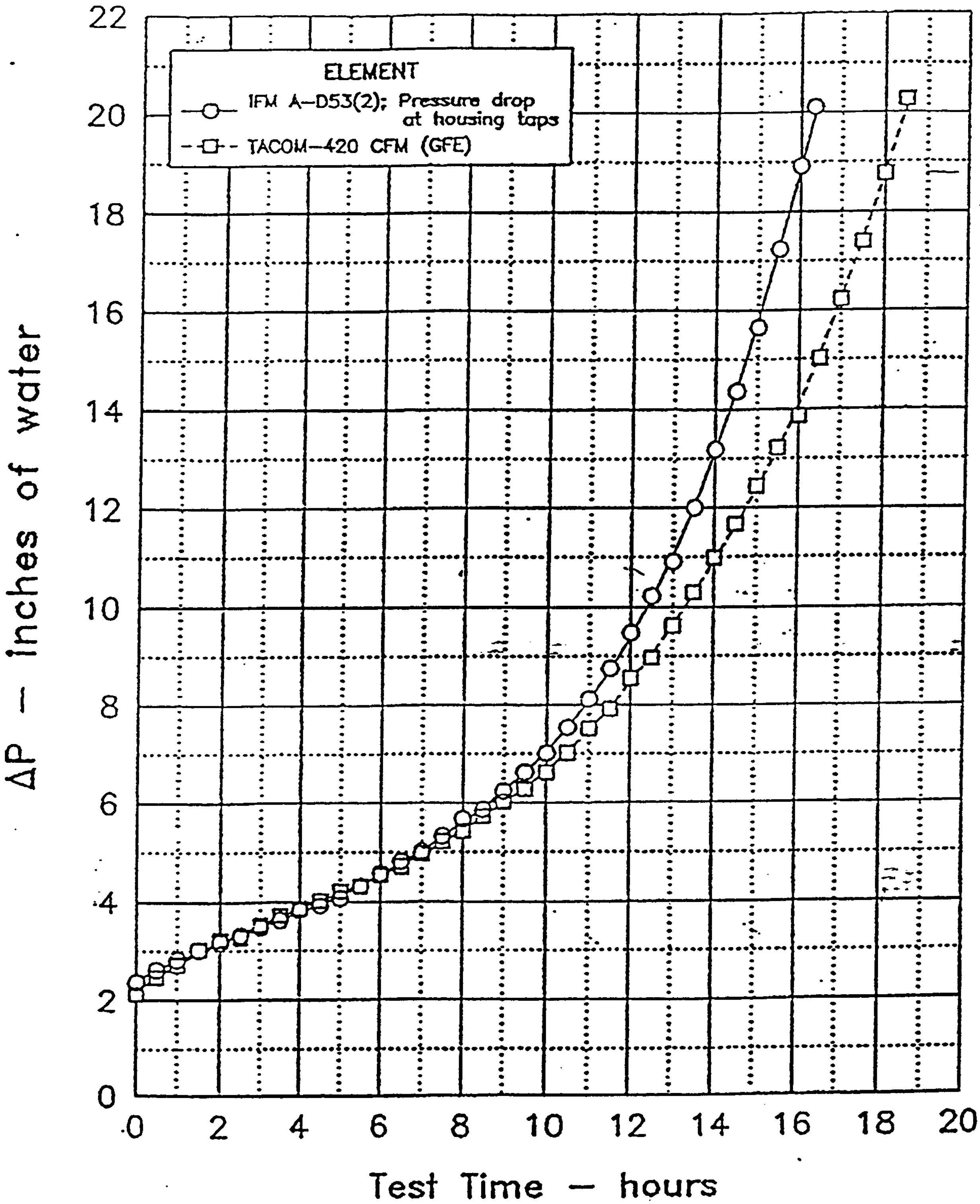


FIGURE 2

SWRI
10/96
MBT
P561

INTERNATIONAL FILTER MFG.

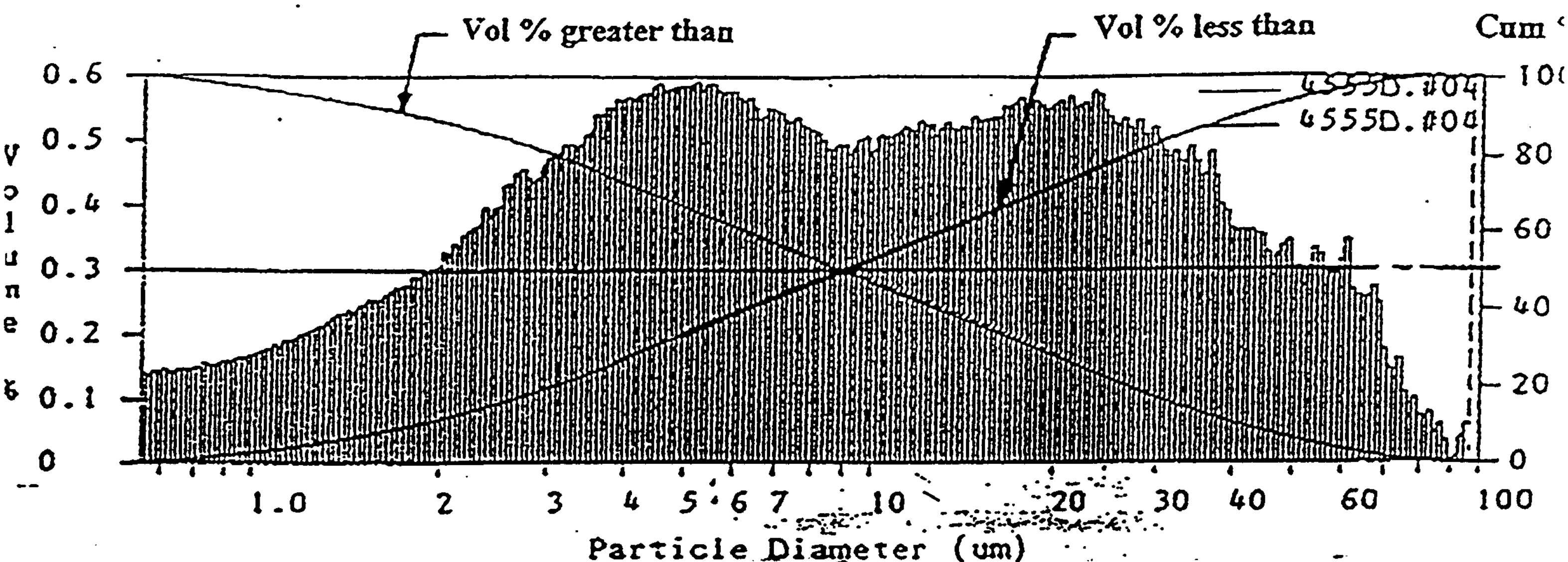
ATTACMENT 1

PARTICLE SIZE DATA FOR TEST DUSTS:

PTI SAE FINE, BATCH 4555D
PTI SAE COARSE, BATCH 4440C

Powder Technology inc.
P.O. Box 1464
Burnsville, Minnesota 55337
Phone: (612) 894-8737

Filename:	4555D.#04		Sample Number:	111
Group ID:	4555D			
Sample ID:	SAE FINE A.T.D.(ISO FINE T.D.)			
Comments:	GENERAL INVENTORY			
Operator:	TAF			
Electrolyte:	ISOTON II			
Dispersant:	TYPE IC			
Aperture Size:	280 um	4555D.#01		
	100 um	4555D.#02		
	30 um	4555D.#03		
Channels	256		Variable 1:	0.000000
			Variable 2:	0.000000
Acquired at:	12:35 Fri May 12 1995			



LC= 0.650 um UC= 96.40 um

Volume Statistics (Geometric) 4555D.#04

:alculations from	0.65 um to 96.40 um			
'olume	$1.182*10^9$	um^3		
lean:	8.712	um	Std. Dev.:	1.158
ledian:	8.840	um		
lean/Median Ratio:	0.986			
lode:	5.200	um		

Cumulative Volume Numeric Data

Micron Size	% Greater Than	% Less Than
1	96.7	3.3
2	88.4	11.6
3	80.1	19.9
4	72.6	27.4
5	65.9	34.1
7	56.2	43.8
10	46.9	53.1
20	28.0	72.0
40	10.1	89.9
80	0.5	99.5

POWDER TECHNOLOGY INC. (612) 894-8737
COULTER COUNTER MODEL TAII PARTICLE SIZE ANALYSIS

CUSTOMER:GENERAL
DATE :28 APRIL 1993
SAMPLE NUMBER : 4440C
PTI RUN NUMBER : N/A
OPERATOR : TAF

MATERIAL : SAE COARSE T. D.
APERTURE : 400,200,100,30
CUST. LOT NO: 60082
MEAN VOLUME : 30.2 MICRONS

COMBINED APERTURE DATA	VOLUME DIFF %	VOLUME CUM %>	DIAMETER (MICRON)
0.00	0.00	100.00	0.198
0.00	0.00	100.00	0.250
0.00	0.00	100.00	0.315
0.00	0.00	100.00	0.397
0.57	0.44	100.00	0.500
0.61	0.47	99.56	0.630
0.73	0.57	99.09	0.794
0.80	0.62	98.52	1.000
1.14	0.88	97.90	1.260
1.49	1.16	97.02	1.590
1.87	1.45	95.86	2.000
2.04	1.58	94.41	2.520
2.69	2.09	92.84	3.170
3.34	2.58	90.75	4.000
3.88	3.00	88.17	5.040
4.32	3.35	85.17	6.350
4.97	3.85	81.82	8.000
5.90	4.57	77.98	10.080
6.81	5.28	73.41	12.700
7.92	6.13	68.13	16.000
8.51	6.59	62.00	20.200
9.51	7.36	55.40	25.400
10.89	8.43	48.04	32.000
11.81	9.14	39.61	40.300
12.09	9.36	30.47	50.800
11.85	9.17	21.11	64.000
9.61	7.44	11.94	80.600
4.32	3.34	4.50	101.600
1.34	1.04	1.16	128.000
0.16	0.12	0.12	161.000
0.00	0.00	0.00	203.000
0.00	0.00	0.00	256.000
0.00	0.00	0.00	322.000
0.00	0.00	0.00	406.000
0.00	0.00	0.00	512.000
0.00	0.00	0.00	645.000

0-2.5 MICRON=
5.6

0-5 MICRON=
11.8

5-10 MICRON=
10.2

10-20 MICRON=
16.0

20-40 MICRON=
22.4

40-80 MICRON=
27.7

80+ MICRON=
11.9

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APPENDIX F